Technical & Business Systems
environmental research associates

T&B Systems Contribution to CRPAQS Initial Data Analysis of Field Program Measurements

Final Report Contract 2002-06PM

Prepared for:

The San Joaquin Valleywide Study Agency

and

California Air Resources Board

Prepared by:

Technical & Business Systems, Inc.
859 Second Street
Santa Rosa, CA 95404

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DISCLAIMER

A. INTRODUCTION

The CRPAQS data analysis was organized in an especially unique manner. Scientists who participated in the measurement program were solicited to propose addressing a list of specific questions that are of interest to scientists and decision-makers. During CRPAQS, T&B Systems was a major participant responsible for aspects of meteorological, particulate mass, and light scattering measurements. As such, we understood that the answers will contain uncertainties owing to limitations in available measurements and basic scientific understanding. In fact, many of the questions directly ask for definition of the capabilities and limitations of the field measurements.

Technical & Business Systems (T&B Systems) was contracted to address a number of questions concerning 1) the adequacy and validity of meteorological measurements, and 2) the ability of the CRPAQS measurements to characterize the critical meteorological features that are known to drive particulate mass loading in the Central Valley.

Portions of specific tasks assigned to T&B Systems included:

Task 1.3: The Adequacy and Validity of Meteorological Measurements

- Subtask 1 Review and summary of existing, recently added and CRPAQS specific meteorological measurements
- Subtask 3 Evaluate the spatial representativeness of wind measurements under stagnation conditions
- Subtask 2 Evaluate the surface mechanical sensor performance relative to the sonics at Angiola
- Subtask 4 Assess the validity of the two-component sodar data collected during stagnation periods
- Subtask 5 Adequacy of the vertical radar and RASS coverage during stagnation
- Subtask 6 Assess the impact of the RASS range gate coverage by comparing to rawinsonde data
- Subtask 7 Assess the usefulness of the routine airplane temperature soundings
- Subtask 8 Assess the temporal adequacy of the measurements made in the surface data to determine if more frequent measurements than one-hour are needed

Task 3.3: How Well Do Measurements Characterize Critical Meteorological Features

- Subtask 1 Transport and Dispersion Under Light and Calm Winds
- Subtask 3 Measurements of Gustiness
- Subtask 4 Vertical Structure of Relative Humidity
- Subtask 5 Spatial and Temporal Extent of Fogs

Task 5.1: Addressing CRPAQS Synoptic Weather Conditions

- A five-year period corresponding to the Fall and Winter field study months were classified by the prevailing synoptic weather types.

Discussions of the questions were reported in a series of Technical Memos submitted to ARB and the Study Agency over the course of the analyses. Those memos are summarized below. Section B comprises the Task 1 to 3 subtasks and Section C, the Task 3.3 subtasks. The weather classification scheme is summarized in Section D.

B. TASK 1.3 ADEQUACY AND VALIDITY OF METEOROLOGICAL MEASUREMENTS

Subtask 1 *Review and summary of existing, recently added and CRPAQS specific meteorological measurements*

The CCAQS database has at least seven sources of meteorological data. Our examination of the data lead to the following observations regarding data quality and representativeness:

ARB – The ARB data are well suited for analyses due to having a well-established QA program, and at least 114 sites exist within the database. The only limitation with the data is that currently the wind speed is only reported to the nearest 0.447 m/s. This limitation, however, does not appear to significantly affect the representativeness of the data.

BAAQMD – the BAAQMD data is essentially the same in quality as the ARB data, except that the reporting resolution is better. Although no comparisons of the BAAQMD data were made, this dataset are also recommended for use.

CIMIS – This data set should be used with extreme caution. Two significant issues regarding the CIMIS data were noted. First, the fact that wind measurements are made at 2 meters instead of 10 meters appears to result in the reported wind speeds decreasing by about 30 percent relative to those made at 10 meters. This can be corrected, for the most part, by using the standard power law adjustment. Second, the results brought about significant questions about the alignment of the wind direction system, with possible misalignments as much as 30° noted. This potential problem was noted at a significant number of sites investigated. The QA program for the CIMIS network is not known.

NOAA – No problems were noted with the NOAA data and the data can be used without qualification by other researchers.

NWS – The NWS data is limited in that wind speeds are only reported to the nearest 0.447 m/s and wind direction only to the nearest 10°. In addition, wind speed comparisons with a “collocated” NOAA sensor showed significant differences. Based on this, use of the NWS data is not recommended.

PG&E (PG) – PG&E wind data were monitored at several different heights, ranging from 10 to 18 meters. Reporting precision is similar to that of NOAA and CIMIS sites. QA for the PG&E sites requires further investigation. Comparisons with other nearby systems were inconclusive.

RAWS (RA) – The RAWS data was not compared, since the complex terrain where most of these sensors are located is representative of local conditions and as such these sites would not be expected to correlate well.

For STI’s initial work in evaluating the representativeness of meteorological measurements for given study areas, they have concentrated on using the CIMIS and NOAA data. Given the issues noted with the CIMIS data, this may need to be reevaluated. Use of the ARB data may be preferred.

<u>Subtask 2</u> ***Evaluate the surface mechanical sensor performance relative to the sonics at Angiola***

There appears to be very little significant difference between the mechanical and sonic wind data. No significant biases are noted between the methods, even at very low wind speeds, and both methods show similar temporal structure. The methods were evaluated by comparing statistics from the time-series of measurements of both direction and speed, investigating the starting thresholds of the sensors, and examining back-trajectories calculated from each of the collocated sensors,

Sonic and conventional mechanical meteorological were co-located at three levels on the tower at the Angiola site. These measurements provided the basis for this evaluation with an emphasis placed on reviewing data during periods of stagnation at the 25-m and 45-m levels. Significant amounts of sonic data were missing at the 95-m level on the tower. Once the sonic data at the remaining levels were adjusted as described below, the two data sets compared very well.

The sonic data as received from NOAA required considerable processing in order to make the data comparable with the mechanical data. The task was made more difficult in that NOAA could not provide any definitive information regarding the orientation of the sonic sensors. NOAA was monitoring primarily for turbulence; thus the actual orientation of the sensor was not required. It was therefore necessary to estimate a correction to actual orientation for the sonic measurements. After processing the averages, comparison of the sonic and mechanical data showed dramatic differences between the wind directions reported by the two methods. However, the two sets of data were highly correlated, and a visual review of the data showed that the sonic data could be converted to coordinates comparable to the mechanical data by multiplying by a slope of –1 and adding 230°. Further discussions with NOAA revealed the fact that the sensors, for convenience, had been mounted upside down, thus accounting for the –1 slope. Furthermore, the 230° intercept is consistent with the sensor boom orientation at 320°, which appears to be the actual boom orientation based on review of existing site documentation and photos. In contrast, it appears that the mechanical sensors were mounted on booms extending 260° from the tower.

<u>Subtask 3</u> ***Evaluate the spatial representativeness of wind measurements under stagnation conditions***

The surface wind network was evaluated on the basis of the spatial distribution of sites coupled with the correlation of measurements between adjacent sites. Our judgment is that the spatial distribution is adequate for both rural and urban settings. Neighboring sites appear to correlate well with each other, with the correlation dropping off in a somewhat predictable manner as distance between sites increases. There appeared to be vane alignment error at several of the CIMIS sites. There isn' t any way to verify this observation. However, it is suggested thathe data be used with caution.

<u>Subtask 4</u> ***Assess the validity of the two-component sodar data collected during stagnation periods***

A review of two-component sodar and conventional meteorological data at the Angiola site was performed for data collected during December 2000, with an emphasis on periods of stagnation. The original intent was to compare the NOAA two-component sodar with the sonic data collected on the 100-m tower. Sodar data that corresponds to the 25-m and 45-m levels of the tower were missing from the measurements--apparently due to noise or reflections at those gates. This left only sonic data collected at the 100-m level available for comparison. However as discussed above, the tower sonic data as received was in a state that required significant processing. Hence, this left the only the mechanical anemometer and sodar data at 96-m available for comparison.

It appears that there are significant differences between winds measured using the two-component sodar and those measured by conventional mechanical wind sensors, especially for wind speed. Given the more direct measurement methodology of the mechanical sensors and their proven agreement with the sonic anemometers, it appears that the differences are due to inaccuracies and limitations with the sodar measurements. The use of the sodar data at low wind speeds introduces additional uncertainty into the analysis.

<u>Subtask 5</u> ***Adequacy of the vertical radar and RASS coverage during stagnation***

An examination of the Angiola site's RASS data was performed for three particularly stagnant periods that occurred during the CRPAQS Winter intensive operations periods. Data from the 100-meter tower were combined with the RASS data. Data from the 23-meter level were removed from the comparison as they appeared to be biased high relative to the other levels on the tower. Each of the combined tower/RASS profiles was evaluated to determine how well the inversion and mixing information was represented in the profile. In particular, the ability to identify or detect the inversion base was of interest as this most likely represented the top of the fog, or mixed layer. Each profile during the IOP periods was assigned a coded type that represented how well the RASS performed in identifying inversion phenomena under various scenarios, based on answers to the following questions:

- Was an inversion noted in the tower data (10 – 98m)?
- Was an inversion noted between the "surface" (10m) tower data and the first RASS gate at 112m?
- Was an inversion noted between the top of the tower (98m) and the first RASS gate (112m)?
- Was an inversion noted in the RASS data above 112m?

Further investigation was conducted to see if the more detailed characterization of the near surface structure provided by the tower could in any way be used to improve assessment of mixing heights. In addition, the issue of a "cold bias" in the bottom gates of the RASS data was investigated by comparing temperature data from the first RASS gate at 112 meters with that from the top of the tower at 98 meters collected during the month of December 2000 and January 2001. This "cold bias" is an issue that has been previously identified as a limitation on the accuracy of the RASS data in the first several range gates.

In general, the RASS data appear to provide a representative depiction of the temperature profile when <u>combined with surface data</u>, despite a lack of data below 100 meters. At least at the Angiola site, the RASS data do not appear to be affected significantly by any "cold bias" problems. However, it does appear that supplying data between the surface and the first RASS gate may allow for more accurate calculations of mixing height, though this is not practical for most monitoring efforts.

<u>Subtask 6</u> ***Assess the impact of the RASS range gate coverage by comparing to rawinsonde data***

Rawinsonde and RASS measurements were purposely not collocated during the field program to optimize resources. However, the RASS units were audited using rawinsondes for comparison. These data provided the basis for this task. Thirty-nine rawinsonde/RASS comparisons were available for review, representing a wide range of meteorological conditions. Five of the RASS units were set to use 60-meter range gates and six were set to 105-meter range gates, providing additional insight into the role of range gate distance.
It was determined that the RASS range gates have a significant effect on the RASS's ability to adequately characterize low-level and surface-based inversions. The RASS did not identify about a quarter of the 35 inversions identified by the rawinsonde soundings. When inversions were identified, their strengths, measured by the lapse rate, were on the order of 67 percent lower for the RASS measurements than for the rawinsonde measurements, due primarily to the RASS's range gate limitation in quantifying the thickness of the inversion layer Some improvement occurs when 60-m gates are used instead of 105-m gates.

<u>Subtask 7</u> ***Assess the usefulness of the routine airplane temperature soundings***

The objective of this task was to assess the usefulness of the routine airplane temperature soundings for determining atmospheric stability and mixing heights. Given the rather unsophisticated method of measurement and quality assurance, and the height interval of the readings (500 ft) there has been a question if the data were of a high enough quality and vertical resolution for use in regional air quality studies and model input. Aircraft soundings are made at 5 PST when the atmosphere is in its most stable state thus some interpolation of conditions during afternoons when the atmosphere has destabilized is required. Moreover, there is some concern that meteorological conditions conducive to high particulate loading would also frequently reduce ceilings and visibility to below minimums required for aircraft operations.

A 15-month set of measurements, which coincidently are sponsored by ARB, were obtained for Central California. On days when rawinsonde observations were conducted at Fresno and Bakersfield as part of the CRPAQS winter program, <u>observed</u> maximum mixing heights were compared to mixing heights <u>computed</u> from the aircraft temperature soundings and maximum daily surface temperature at Fresno and Bakersfield.

It was concluded that the aircraft data can provide useful, often accurate mixing height information if the general meteorological conditions are not rapidly changing during the day. With that caveat, it is recommended that the other ARB airplane soundings in Central California be utilized in this manner wherever RWP or RASS data are not available. Other airplane sounding locations of relevance to CRPAQS are at airports in Sacramento, Modesto, and Trimmer.

<u>Subtask 8</u> ***Assess the temporal adequacy of the measurements made in the surface data to determine if more frequent measurements than one-hour are needed***

The majority of meteorological variables are scalar, with more or less steady rates of change. In general, meteorological measurements at frequencies less than one hour therefore are not anticipated to provide much additional information. The obvious exception to this is the wind data, which is quite variable and discontinuous and thus most often expressed as a vector measurement.

To investigate the significance of differing averaging intervals, comparisons were made between 1-hour and 5-minute vector wind data from the 10-meter level of the Angiola tower. While the summation of vectors will remain the same regardless of the frequency of the data, the 5-minute vector data will almost always take a more meandering path than the 1-hour data. To investigate this, hourly wind run values were calculated for both the 5-minute and 1-hour vector data for the month of December 2000

On average, use of the 5-minute data results in hourly wind runs that are about 0.43 kilometers greater than those obtained using the 1-hour data. In our estimation, this difference is not significant for most applications. This difference is fairly consistent throughout the dataset, with little dependence on wind speeds, especially for wind speeds less than 2.5 m/s.

C. TASK 3.3 HOW WELL DO MEASUREMENTS CHARACTERIZE CRITICAL METEOROLOGICAL FEATURES

Subtask 1 *Transport and Dispersion Under Light and Calm Winds*

In this task, the ability of the CRPAQS network to adequately define important transport processes under light wind conditions are examined. The ability of the methods employed to measure light winds accurately --both at the surface and aloft-- was addressed in the various Tasks of work element 1.3. Task 2 of work element 1.3 demonstrated very good comparability of conventional wind measurements with the more sensitive sonic measurements, even under light winds. Task 3 showed that closely located monitoring sites had well correlated winds. Task 4; however, suggested differences between Sodar and conventional wind measurements at low wind speeds, likely due to limitations with the Sodar. These two work elements are inherently related. It should also be noted that all the wind profiler sites were audited, and the measurements compared with measurements made by a different method (i.e., rawinsondes) over the diurnal cycle, which usually included light winds and vertical shears.

During meteorological scenarios that produce light to calm winds within the surface boundary layer, there are often strong vertical wind gradients. Therefore, it is critical to accurately define the vertical wind profile at representative areas in the study domain in order to understand the three-dimensional transport processes. In this task, the focus was on the reasonableness of the measured winds when boundary layer winds are challenging the lower threshold of the monitoring equipment. This was accomplished examining resultant air parcel trajectories versus uncertainty estimates, volume fluxes, and vector differences at three sites that represent conditions on the west side, central and east side of the SJV along a SW-NE transect.

Radar wind profilers appear to characterize light winds reasonably well, and define vertical wind shears. Substantial differences in the magnitude and direction of the winds were observed above the boundary layer but below the complex terrain that defines the SJV. It is important to note that the field study design selected upper air sites as to not be redundant. The differences observed in the low-level trajectories are very reasonable considering the light and variable nature of the wind field and local topographic differences. It is interesting to note that over the diurnal cycle, fluxes for two or more of the sites were in excellent agreement, and that all three sites shared similarities (i.e. none of the sites appeared as outliers throughout the entire diurnal cycle). The final data validation is how consistent three-dimensional wind flow analyses are with the areal distribution of pollutants.

Subtask 3 *Measurements of Gustiness*

A number of stations reporting meteorological data during CRPAQS included wind gust (or peak wind) as one of their measurables. This task investigates the usefulness of wind gust data in relation to the understanding of the origin of suspended particulate matter within the CRPAQS study area. Since gustiness is a short-term phenomenon, continuous particulate measurements (as opposed to long-term integrated sampling) are of particular interest. In addition, because gustiness is highly localized, the sites examined were required to have particulate measurements and meteorological measurements collocated. Lastly, wind-borne dust is associated principally with dry soil conditions.

The CRPAQS central monitoring site at Angiola provided the best source of such data. This site had collocated b_{sp}, $PM_{10,}$ and $PM_{2.5}$ measurements and represented the agricultural areas that comprise a large portion of the CRPAQS study area where fugitive dust could be an issue. Wind-gust data were also recorded at Angiola, though meteorological data were missing for September through November 2000, a period characterized by typically dry conditions.

The Angiola data provided evidence that winds at prevailing speeds of approximately 8 m/s or greater contribute to coarse particle concentrations. The data also suggested a relationship between wind gust and wind speed hourly average. Typically, gusts of around 10 m/s are associated with an 8 m/s average, and it is unclear as to how much additional information peak wind speed data provides beyond average wind speed data. However, there are indications that higher gusts associated with lower wind speeds (e.g., 10 m/s gusts when average wind speeds are closer to 6 m/s) may provide explanations for a portion of the observed higher coarse mass concentrations.

Also, a more general survey of peak wind gust was conducted using the 10-meter wind data collected by NOAA for CRPAQS. This dataset represented a consistently operated, quality assured source of gust data, with a 19-site network that evenly represented all of the meteorological domains within the CRPAQS study area. Review of the NOAA data therefore provided a good opportunity to identify difference in the gustiness of the wind that could be significant. Frequency distributions for the complete study period were created for both average scalar wind speed and peak wind speed for each site, for four meteorologically defined seasons.

There was a similarity in wind and gust profiles between sites of similar domain characteristics. The following categories emerge:

- Coastal passes. Characteristics include a relatively low frequency of low average and peak winds, with a peak in the frequencies around 5 m/s. In general, there are higher winds in the spring and summer, though winds are always higher than those for other sites reviewed. The peak wind speed distribution is significantly shifted in the positive direction relative to the average wind speed distribution. This profile includes Altamont Pass, Pacheco Pass, and Richmond.

- Central Valley sites, including low, eastern foothills. This is the largest category, consisting of over half of the sites reviewed. Characteristics include a high frequency of low average wind speeds, though the frequency of low peak wind speeds is often much lower than that of low average winds speeds. In general, there is a less pronounced shift in the peak wind speed profile then there is for the coastal passes. This profile includes Auburn, Bakersfield, Chico, Chowchilla, Fresno, New Melones Dam, Redding, and Trimmer. The profile for Gaviota is also similar.

- Frequency distributions with peaks at about 4 m/s. Four sites have winds that have neither the consistently high distribution of low wind speed like the valley sites nor the high wind speed from the coastal passes. In addition, there is frequently little difference between the average and peak wind speed distributions, indicating less pronounced gusts. These sites include Arbuckle, Kings River Powerhouse, Lost Hills, Pleasant Grove, and Tejon Pass. All of these sites have the potential for influence by nearby topography.

- Mojave. The Mojave profile is unique, most likely due to its unique, high desert location relative to the other CRPAQS sites. This site has the highest winds and the biggest differences between the peak and average wind speed distributions.

- Waterford. The profile for Waterford does not really match any of those for the other categories. The most distinctive feature is that the peak wind speed profile is significantly shifted upward relative to the average wind speed profile, indicating a gustier site.

The data suggest that gustiness plays a relatively small role in generating fugitive soil in the CRPAQS domain as the majority of the sites are characterized by low wind speeds during the dry seasons. Even sites with wind speeds more frequently in the 4 m/s or above range show a relatively small difference between average and peak wind speeds. Of the sites reviewed, only the coastal pass sites, Mojave, and Waterford have profiles that are characteristic of gusty conditions. In addition to these generalizations, the following, more specific observations are made regarding the frequency distribution plots:

- Several of the central valley and eastern foothill sites demonstrate more noticeable gusty conditions during the spring and summer months (March through September). This includes Auburn, Fresno, and to some degree New Melones Lake, Redding, and Trimmer. It should be noted that his is directly opposed to the high PM periods of interest for CRPAQS (the fall and winter), again downplaying the role of gustiness for CRPAQS.

- The Auburn site has a unique "jag" in the peak wind speed frequency distribution that persists through both the spring and summer periods. Its uniqueness implies the possibility that gustiness is a function of something other than wind speed, such as direction.

In conclusion, there is evidence that winds at speeds of approximately 8 m/s or greater can contribute to coarse particle concentrations. Typically, gusts of around 10 m/s are common at this average speed, and it is unclear as to how much additional information peak wind speed data provides beyond average wind speed data. However, there are indications that higher gusts associated with lower wind speeds (e.g. 10 m/s gusts when average wind speeds are closer to 6 m/s) may provide explanations for higher coarse mass concentrations.

High wind speeds and gusts are likely to be rare in most of the CRPAQS study area, and the data available for determining the relationship between coarse mass concentrations and wind gusts is limited. Continuous b_{sp} measurements were much more common in the CRPAQS study area, and while these measurements are more closely associated with $PM_{2.5}$, there appears to be a contribution associated with high wind speeds and gusts.

Subtask 4 *Vertical Structure of Relative Humidity*

NOAA meteorological stations deployed during CRPAQS measured temperature and relative humidity at both 2 meters and 10 meters above the ground surface on the same tower. This provided an opportunity to compare readings made by identical instruments and operating procedures--the only difference being the height of the sensors. Three (3) sites in the SJV were examined: Bakersfield, Fresno, and Chowchilla.

Humidities were generally the lowest during the daytime in response to warmer ambient temperatures relative to nighttime. Beginning late in the afternoon, RH increased to values often in the 90-100 percent range from midnight to daybreak. RH in the lowest 10 meters is relatively constant during day when that layer is well mixed.

Over the diurnal cycle, the largest differences occur in the early evening as the ground cools averaging 5 to 7 percent RH at the three sites. During the day, average differences are within 0.5 percent RH—well within the accuracy of the sensors. RH differences were as high as 15 percent at Chowchilla, 10 percent at Fresno, and 14 percent at Bakersfield. Humidity at the two heights was extremely well-correlated. Correlation coefficients were 0.98, 0.99 and 0.99 at Chowchilla, Fresno, and Bakersfield, respectively.

Temperature differences between the 2- and 10-meter levels also varies over the diurnal cycle. The average ambient temperature inversions are on the order of 1 ^{o}C are characteristic of nighttime while the average daytime differences remain 0.5 ^{o}C or less.

Dew point is a function of temperature and relative humidity and a more conservative characteristic of an air mass than either. The average difference in dew point over the diurnal cycle is generally less than 0.2 ^{o}C. Thus measurements of humidity made at any height on a meteorological tower can be normalized to dew point temperature.

PM chemistry model meteorological inputs are relative humidity and ambient temperature not dew point temperature. DRI model results show PM levels respond substantially to changes in relative humidity. An example set of runs assuming a 10 percent error in RH results in a 25 percent difference in PM loading. This is noteworthy in that RH sensors are not mounted at any standard height. For example, the BAAQMD typically mounts the sensor near the top of the 10-meter tower whereas CIMIS mounts all their sensors at 2-meters. Other RH sensors in the network are located on the roof of monitoring trailers or on building rooftops (e.g. Fresno Supersite).

At this time, the CRPAQS database does not include sensor height above the ground. Moreover, it is not clear what sensor height is appropriate for the model calculations. The best solution would for the models to use a more conservation moisture variable if possible.

Relative humidity was measured at 5 levels on the 100m Angiola tower thus offered an opportunity to examine the vertical structure of the lower boundary layer. Noteworthy characteristics included:

- From late morning until late in the afternoon, humidity readings tracked very closely at the sensors above 10m. Relative humidity was generally higher at 10m (<10% RH on the average); and
- At night as the atmosphere stabilizes, a gradient from higher to lower RH develops averaging ~10-13 percent.

This general RH behavior does vary significantly on a day-to-day basis. For example, on December 6 the fog layer was deep and persistent resulting in near saturation at all levels over the diurnal cycle. On December 8, RH was ~100 percent at 10m throughout the diurnal cycle but varied substantially above.

Rawinsonde measurements did not exhibit the vertical variation detail in RH measured on the Angiola tower. This feature is likely due to a couple of factors. One, the rawinsondes used in this project are primarily used to measure synoptic-scale properties rather than the sub-mesoscale which is the focus this project. As such, the humidity elements are of a relatively high mass thus having a correspondingly long response time. Secondly, to measure the detail in the wind and temperature aloft, which is the primary objectives for the rawinsonde observations, balloon ascension rates were scaled down to manufacturer' s minimums that may have reduced sensor response times even more.

Subtask 5 ***Spatial and Temporal Extent of Fogs***

In the IMS95 data analyses, the presence of fog was inferred when surface relative humidity exceeded 95 percent and thereby used to describe the areal and temporal extent of fogs. This approach proved useful in that study hence was utilized again in this study. Measurements from over 150 sites were used to prepare regional maps depicting the number of hours that RH exceeded 95 percent. Daily maps were developed for the average number of hours RH exceeded 95 percent over each IOP, and for the average number of hours RH exceeded 95 percent for each of the CRPAQS winter intensive monitoring days.

The key characteristic of the set of fog charts is that there are significant differences between the IOPs. During the first CRPAQS Winter IOP, December 15 to 18, RH measurements infer that fog was somewhat extensive throughout the SJV except in the Bakersfield area where fog occurred only occasionally. Fog was heavy in patches along the west side. Occasional fog occurred in the Bay area and SacV except in the Sacramento area where fog was intermittent.

From around Angiola north, fog was frequent in the Central Valley during the December 25 to 28 period. Only light fog occurred in the southern SJV and along its southwest edge. The Bay Area for the most part experienced little or no fog.

Noteworthy is that fog was only sporadic in the southern half of the Valley during the January 4 to 7 period when PM loading was the greatest. There was extensive heavy fog in the Delta and Sacramento area. Fog was uniformly merely "occasional" in the Central Coast basin. Fog in the Bay Area was very non-uniform, ranging from heavy at some sites with clear skies prevailing at others.

During the last IOP, moderate to persistent fog was the rule in the Modesto/Merced areas, in the Sierra foothills, and Tulare Lake basin. Generally only isolated instances of fog occurred in the Bay Area, northern SJV and Sacramento area.

The most significant variation in the fog extent occurred from day-to-day within an episode. Daily fog charts have been prepared in order to document that variability. Their primary utility is to assist the other researchers examining specific air quality features. We also produced daily spatial maps of $PM_{2.5}$ loading on the same scale as the fog charts, and compared the spatial patterns. These charts depict the isopleths of PM mass as well as the actual 24 hr mass measurements. These charts were created with only the readily available data for the Satellite network that was operated T&B Systems. They do not include the Anchor site measurements.

Any direct relationship between PM loading and fog intensity and areal distribution was not evident from the chart comparisons. This feature is illustrated in the January 5 and December

18 data. January 5 experienced the peak particulate loading during the CRPAQS Winter study and December 18 experienced some of the least PM2.5 levels.

D. TASK 5.1 CRPAQS SYNOPTIC WEATHER CONDITIONS

Weather Typing Subtask

Synoptic weather patterns were classified into particular pattern types with the objective of assisting in describing the various fine particulate episodes experienced in the Central Valley of California. By examining the number of occurrences of the various types of synoptic patterns during the peak particulate loading months (October through February) for a five-year period (1999 through 2003), any long-term trends in the meteorology will be described and the representativeness of specific episode events (i.e., SIP design days) can be determined.

The basic premise of the classification scheme is that the synoptic scale weather characteristics, as demonstrated by the 500 mb constant pressure patterns, strongly influence the existence, distribution and duration of air pollution episodes in the California Central Valley. Five basic weather pattern types are postulated in this report:

T Troughing. Cyclonic influence, resulting in excellent mixing, deep to unlimited mixing layers and cool air advection aloft. Synoptic patterns include long wave troughs, closed lows, zonal flow and transitory short wave troughs.

PR Pacific Ridge. Eastern Pacific ridge centered off shore, producing fresh well-mixed cool air advection into the Central Valley. Flow aloft is northerly, often with a strong gradient. Situation usually follows a cyclonic event and is the initial anti-cyclonic condition.

CR Coastal Ridge. Anti-cyclonic synoptic pattern over Pacific coast, usually the central portion of a broad ridge of high-pressure at the surface and aloft. Condition is often an extension inland of the eastern Pacific ridge. Situation is characterized by a stable air mass, with week pressure gradients, and a subsidence stable layer cap over the lower boundary layer. Mixing is inhibited, and regional pollutants are trapped under the cap.

IR Interior Ridge. Great Basin high-pressure ridge, with highest pressures located in the interior west. Often produces offshore flow conditions in California at the lower levels, and is most significant in the fall. The air mass is stable, usually with a strong subsidence cap over the boundary layer. Low-level gradients can often be locally strong.

PT Pre Trough. The back (west) side of an interior ridge (IR), or the late (dying) stages of a coastal ridging (CR) event. The air mass is still quite stable and poorly mixed, with a subsidence cap trapping pollutants in the lower boundary layer. Pressure gradient flow becomes increasingly southerly in the lower levels as cyclonic conditions approach from the west. Often the poorest mixing occurs just before cyclonic mixing begins.

The daily 500 mb synoptic weather patterns, at 1200 UTC, for the five year analysis period were examined and classified into one of the five categories listed above.

As might be expected for the late fall and winter months, the single category with the most occurrences was the troughing (T). The T condition, along with the Pacific ridge (PR) pattern is associated with well-mixed good dispersion and generally low pollution loading regimes. The possible exception in the Central Valley could be elevated pm loading in the lower boundary layer due to locally high winds. Combined, the T and PR conditions occurred 66 percent of the time during the period in question. Of the stable, high pollution potential conditions that occurred 34 percent of the time, the coastal ridge CR regime was the most frequent, occurring at a rate of 21 percent.